An Integrated Outcrop and Subsurface Facies Analysis of the Albian-Cenomanian Nanushuk Formation near Umiat, National Petroleum Reserve, Alaska*

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Search and Discovery Article #50374 (2011)
Posted January 18, 2011

*Adapted from oral presentation at AAPG International Conference and Exhibition, Calgary, Alberta, Canada, September 12-15, 2010

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Abstract

The Umiat reservoir lies beneath Umiat Mountain on the southeastern boundary of the National Petroleum Reserve Alaska (NPRA). The reservoir is thought hold as much as 200-300 MMBO of recoverable reserves, but remains undeveloped due to challenges caused by its shallow depth (275-1250 ft) and the presence of permafrost. These complicating factors increase the value of a detailed facies model for the Umiat reservoir.

Current research is directed toward the development of a high-resolution facies model that combines independent study of core and outcrop with published well log and core analyses from public and private sources. The goal of the integrated core and outcrop study is to assess both vertical and lateral variability within the reservoir. Outcrop investigations were undertaken in order to better understand sedimentary structures, stratal geometries, and stacking patterns observed in core, and to overcome issues with core preservation and quality. Though the reservoir units are not expressed at the surface at Umiat, local outcrops provide useful analogs for depositional environments described in the Umiat cores.

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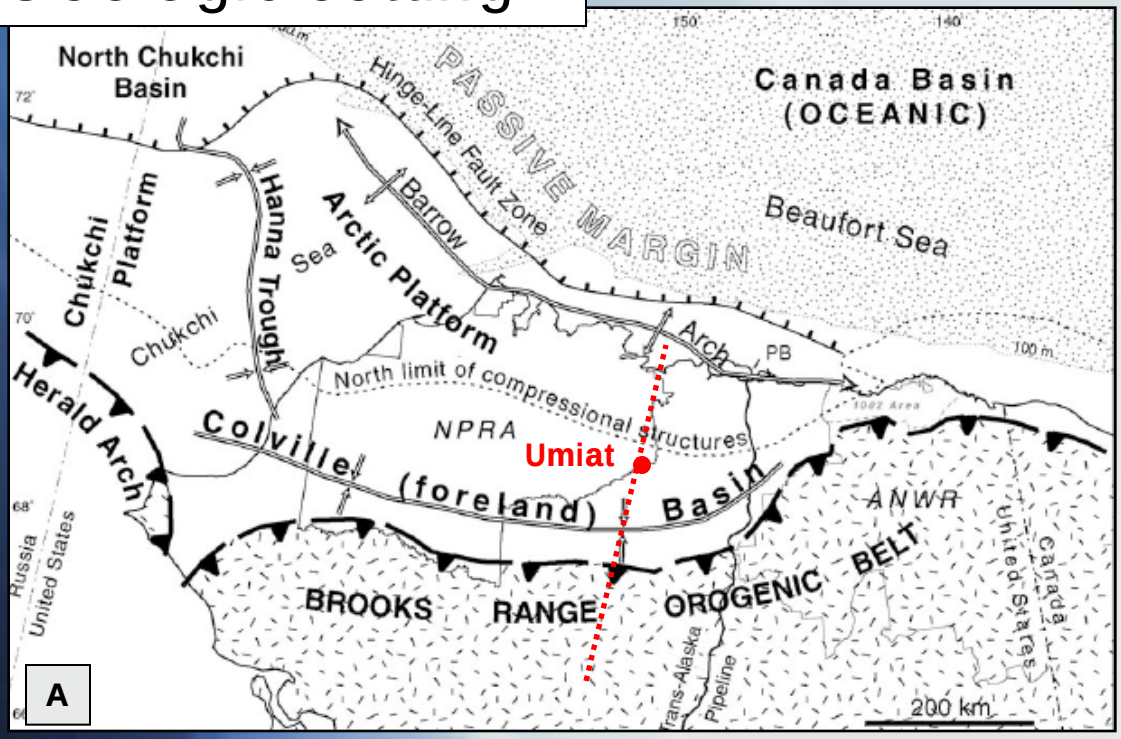
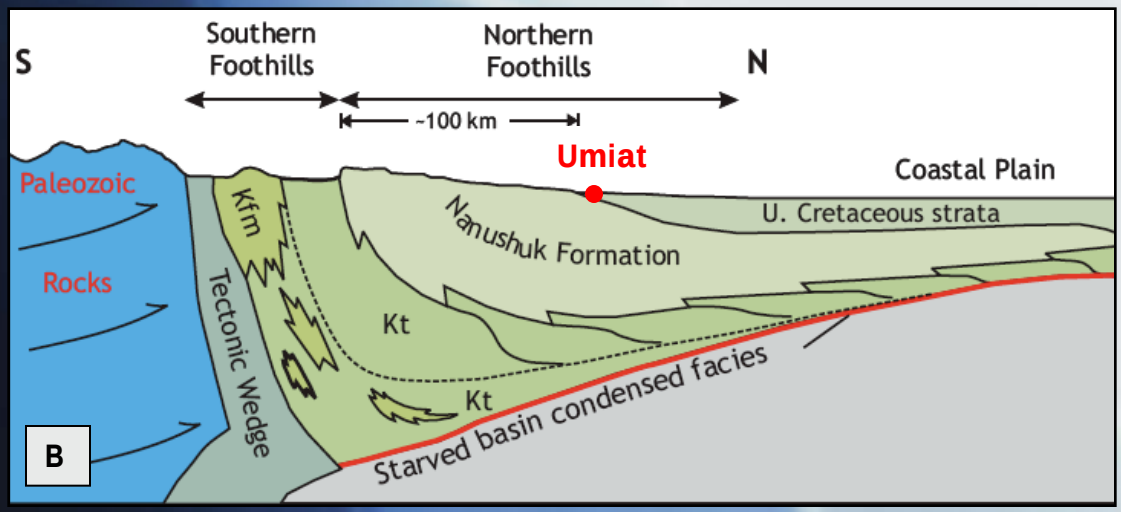
Geology and Geophysics, Petroleum Engineering, Geophysical Institute

Financial, Logistical, and Travel support:

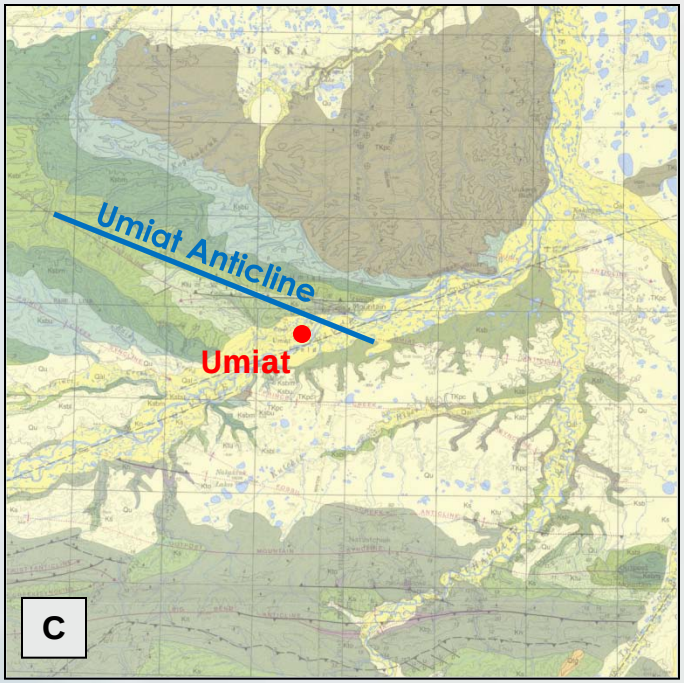
Geologic Setting





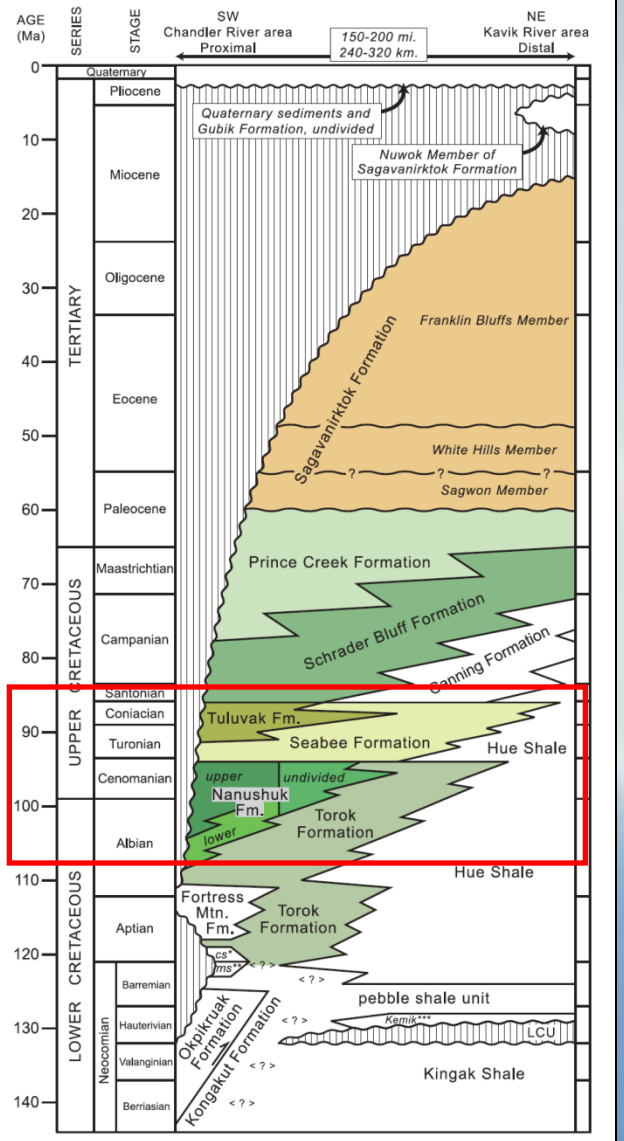
Umiat

- Alaska's North Slope
- Brooks Range
  - foreland basin
  - fold and thrust belt
- the Umiat anticline



A. Figure from Bird, 2001; **B**. Figure from Lepain and others, 2009; **C**. Modified from Mull and others, 2004

Geologic Setting: Regional Stratigraphy



Umiat

- Cretaceous: Albian-Coniacian age
- Three major formations in core
  - Seabee Formation
  - Nanushuk Formation
  - Torok Formation
- Deposited in the Colville Basin (foreland)
- Focus on the **Nanushuk Fm.**

informal nomenclature

Nanushuk	Ninuluk	marine
	Chandler	non-marine
	Grandstand	marine

Stratigraphic column from Mull and others, 2003

Umiat: an unconventional reservoir

Why Unconventional?

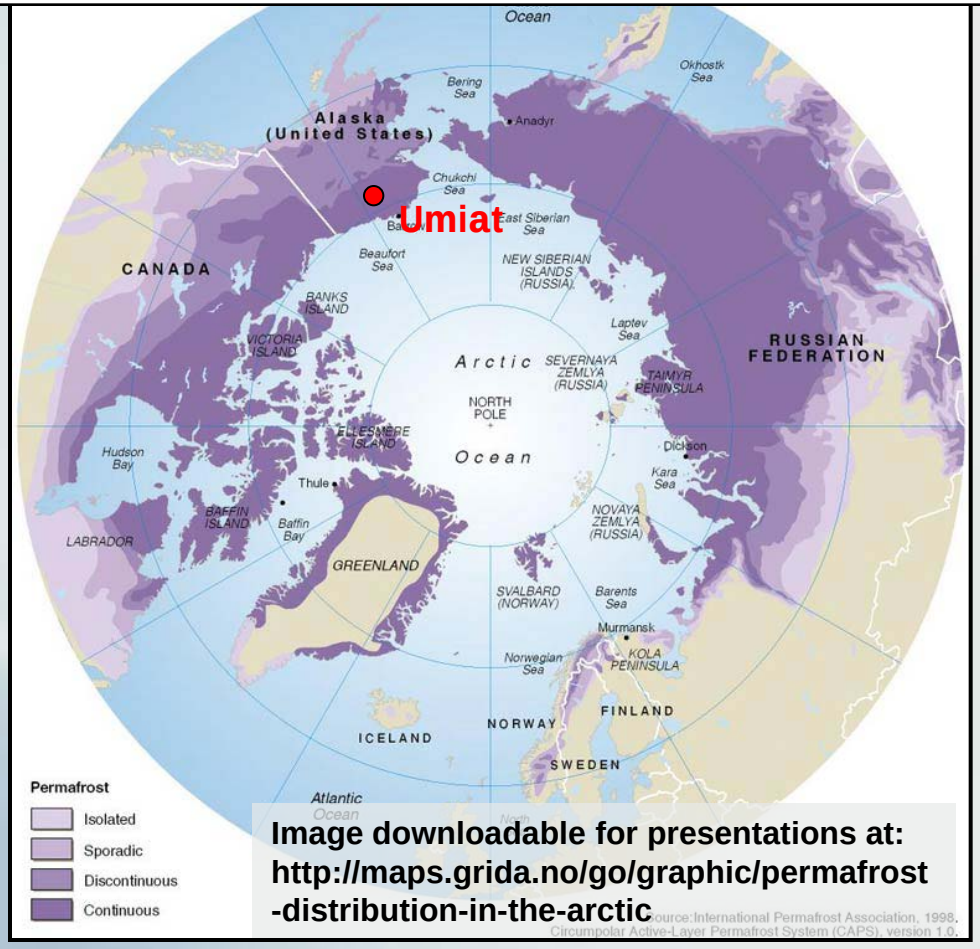
- shallow depth (275-1100 ft)
- light oil, not degraded
- presence of permafrost
  - depth affects temperature
  - ice in pore space

The Umiat Wells

- drilling from 1945-1953
- 11 test wells
- limited recovery:
  - structure
  - stratigraphy
  - permafrost

Permafrost distribution

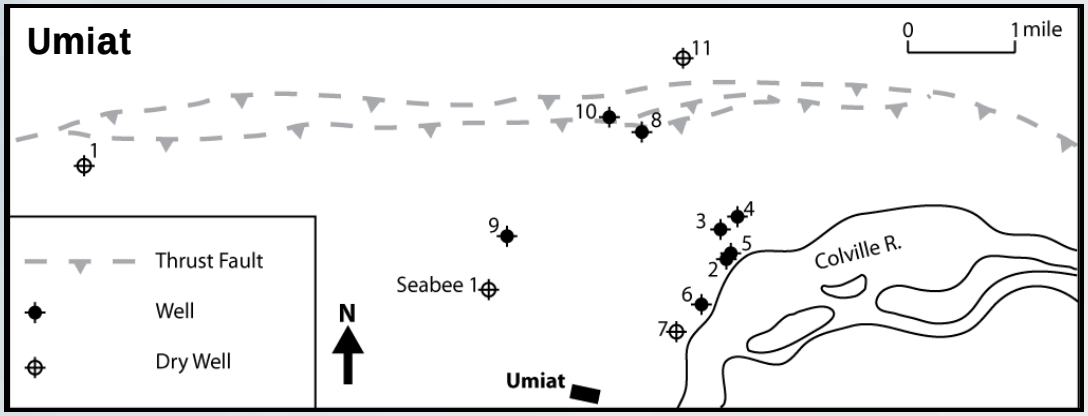
- defined by *temperature*: soil or ***rock*** at or below freezing (0º C) for 2 or more years
- up to 1055 ft deep in the Umiat area

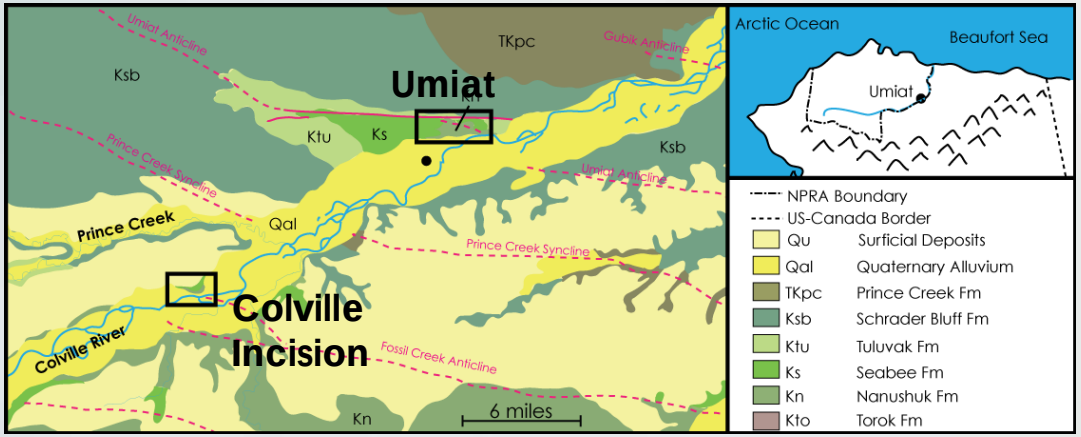


Facies Model: Facies Associations

Facies Associations

- Focus on Nanushuk Fm.
- Core from 11 wells
- Fieldwork: “Colville Incision”
- Published data
  - cuttings
  - microfossils
  - permeability
  - limited well logs





Nanushuk Formation Facies Analysis

- 7 facies associations
- 3 potential reservoir facies associations

Umiat figure modified from Houseknecht and Schenk, 2004; Geologic map modified from Mull and others, 2004.

Facies Associations

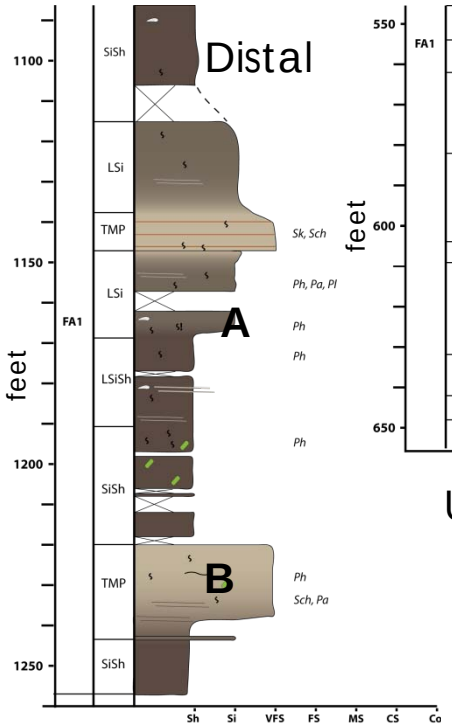
FA 1: Offshore

- **lithology**: silty shale to sandy silt
- **structures**: lenticular, wavy bedding
- Cruziana ichnofacies

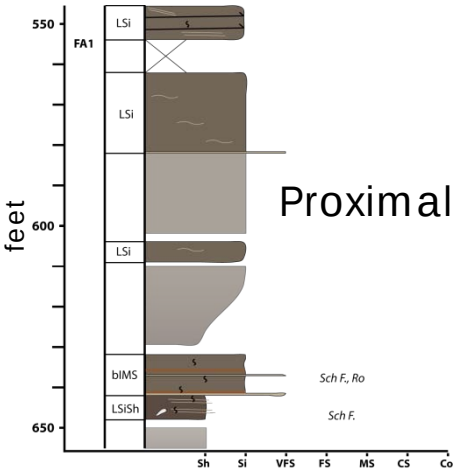
silty shale

Phycosiphon

storm beds



Umiat Well 9



Umiat Well 2

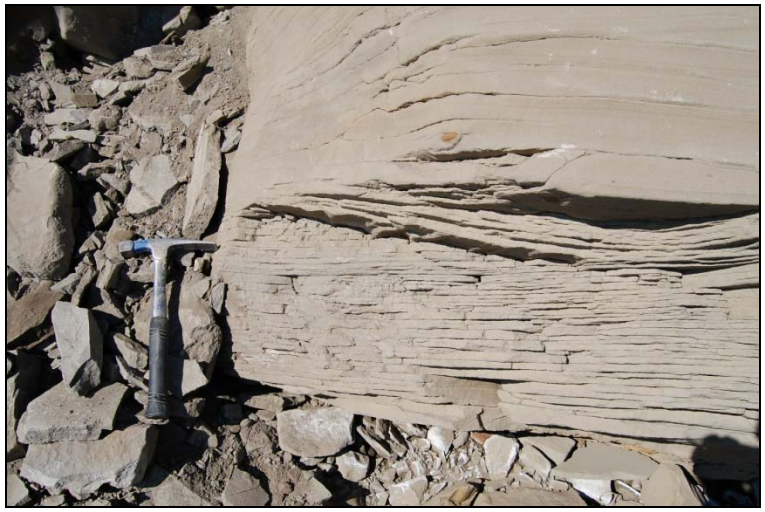
- prodelta and delta front mudstones
- silts represent more proximal delta front deposits
- rare sandy storm deposits

Facies Associations

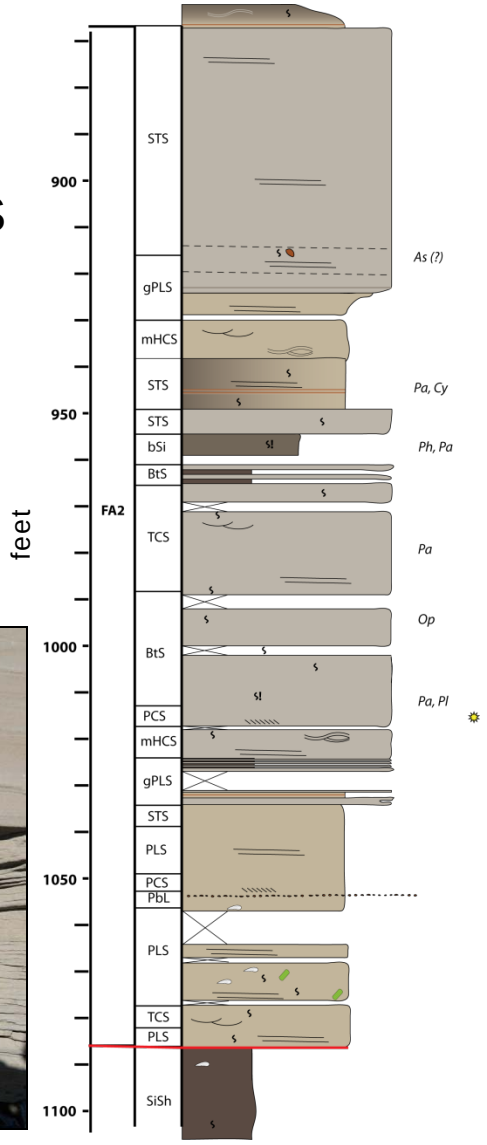
FA 2: Storm-influenced shoreface

- **lithology**: very fine to fine sand
- **structures**: low-angle cross bedding, HCS
- sharp contact with underlying mudstones
- often structureless, bioturbated
- prevalent in all wells
- common at the Colville Incision (CI)

HCS



low angle trough cross beds/HCS



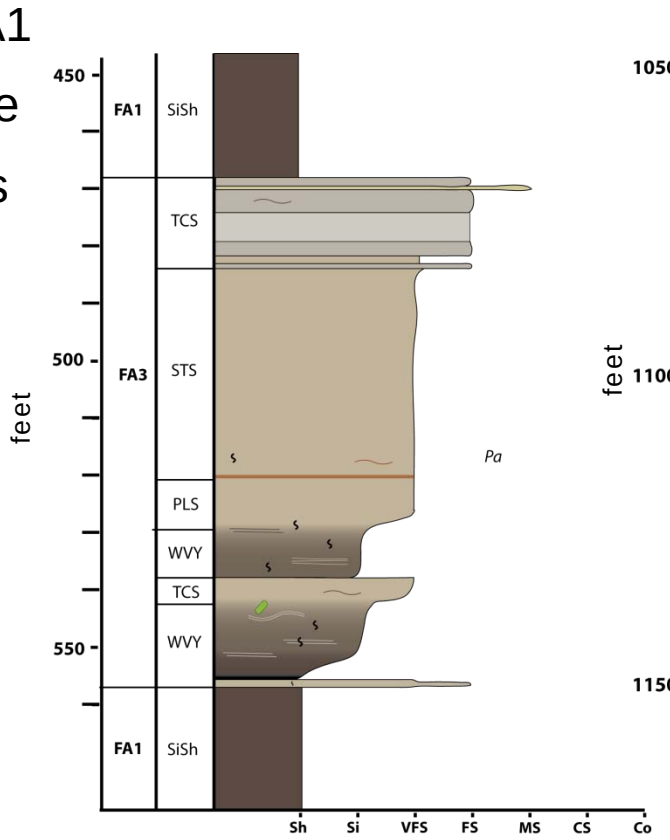
Umiat Well 9

Facies Associations

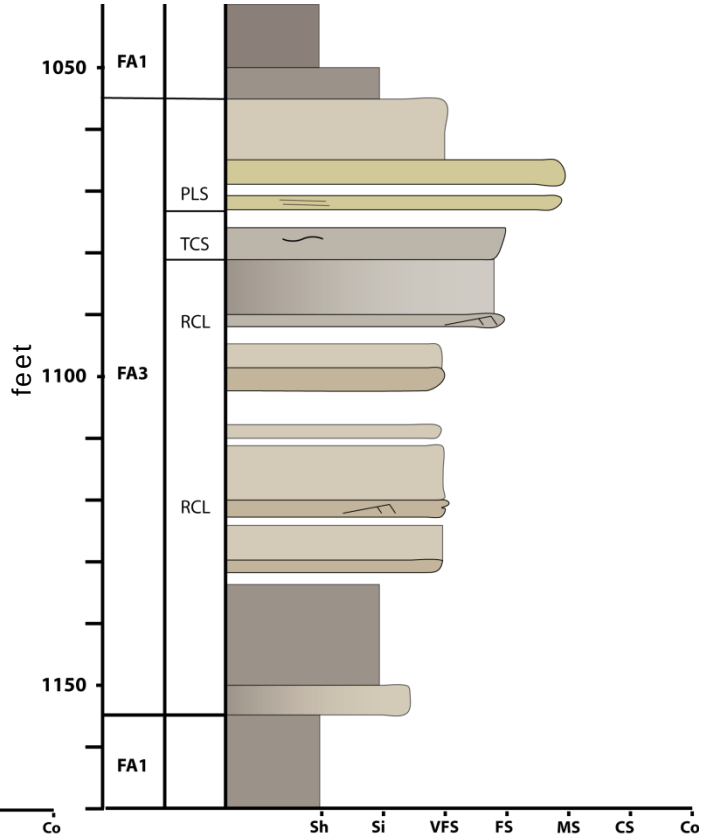
FA 3: Distributary mouth bar

- **lithology**: silt, very fine to med sand
- **structures**: low-, high-angle trough cross bedding
- coarsens up from FA1
- some storm influence
- carbonaceous debris
- prevalent in all wells

coalified plant debris



Umiat Well 9



Umiat Well 10

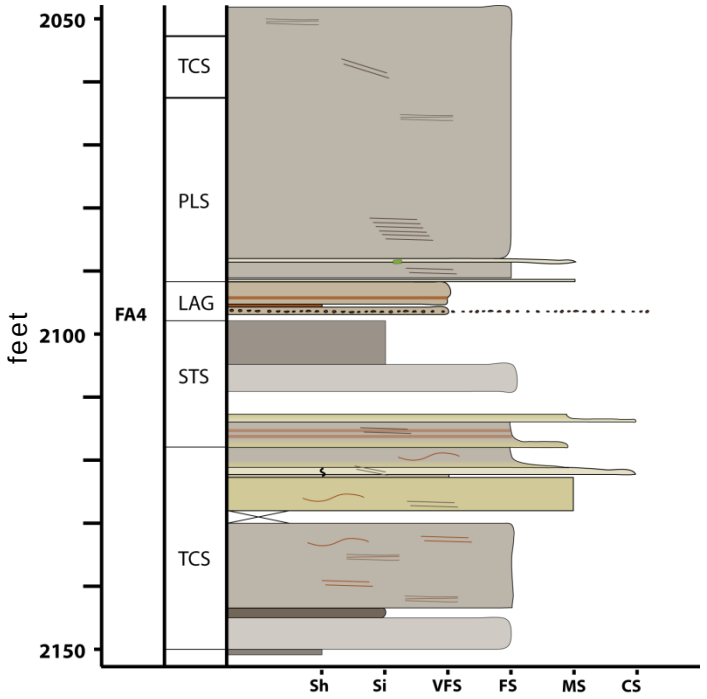
Facies Associations

FA 4: Distributary channel

- **lithology**: fine to medium sand, pebble conglomerate
- **structures**: asymmetrical ripples, high-angle laminations, pebble-cobble lags
- ichnofossils rare to absent

foreset dip >15º

mud drapes



Umiat Well 11

- coarser grain size represents higher energy
- mud drapes representing tidal influence
- rarely observed, more common in Umiat well 11

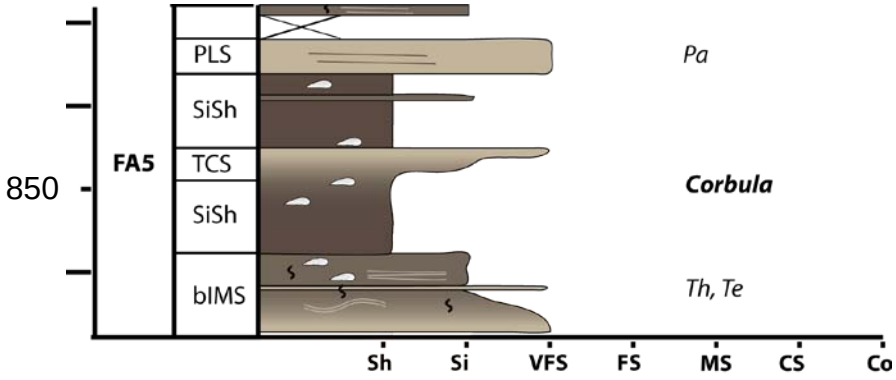
Facies Associations

FA 5: Bay fill/estuarine

- **lithology**: shale, silt, coal
- **structures**: lenticular-wavy bedding
- shell layers common
- brackish water
- relatively rare

synaeresis cracks

shell beds



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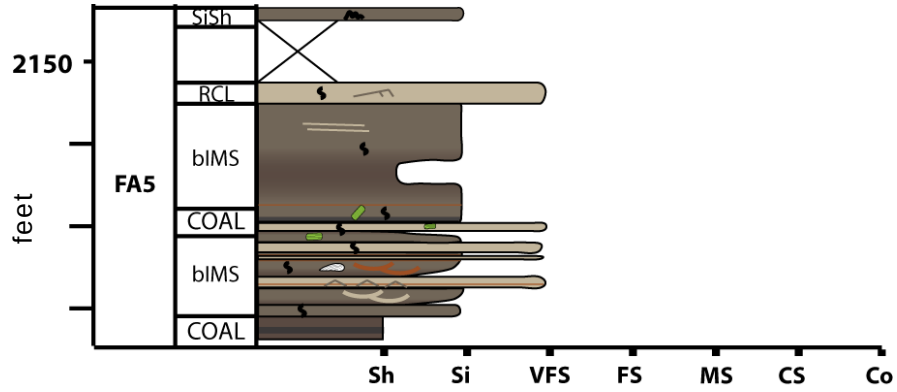


Umiat Well 11

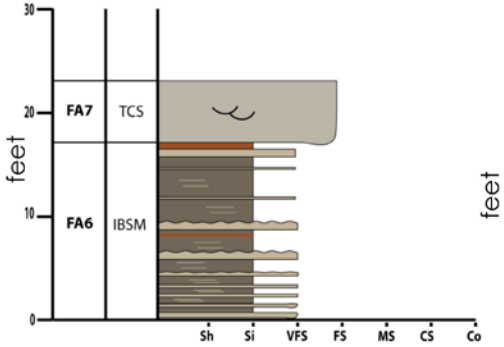
Facies Associations

FA 6: Delta plain

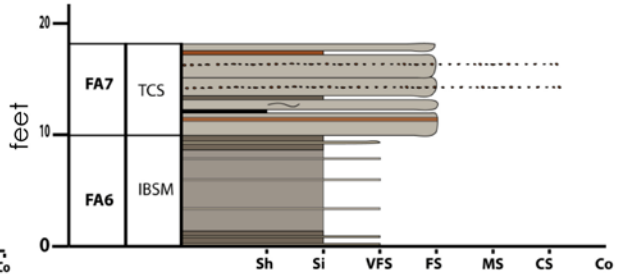
- **lithology**: silt, some very fine sand
- **features**: laminated mud, coaly layers, crevasse splays

FA 7: Fluvial Channel

- **lithology:** very fine to fine sand
- **structures**: soft sediment deformation, current ripples, lateral accretion surfaces, channel lag deposits



Cl 9



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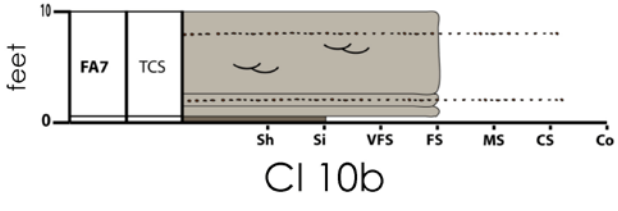
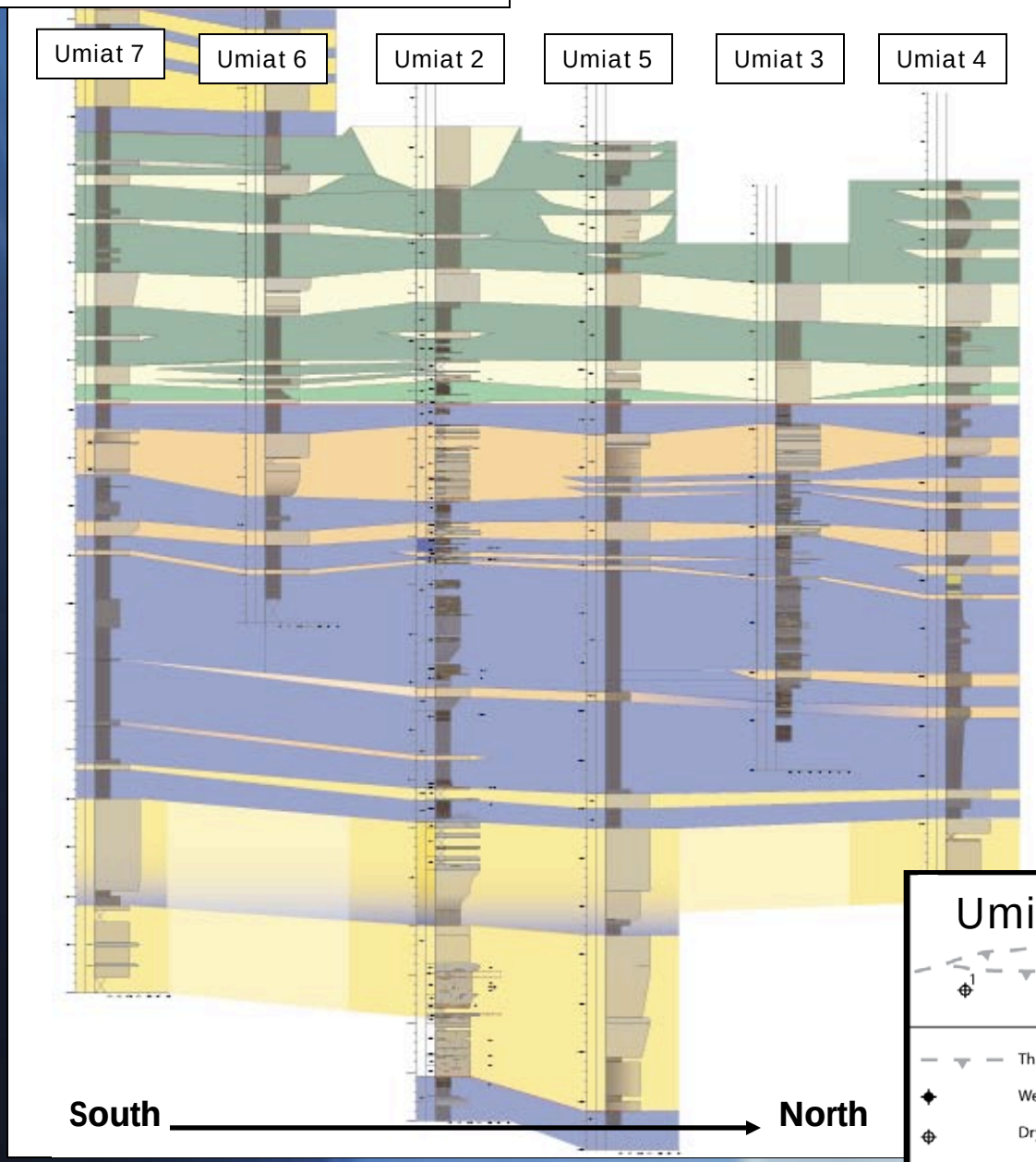


Cl 10b

Notes by Presenter: Interpretations: Fining upwards and channel abandonment. Distinct from FA4, non-marine deposits. Poorly represented in recovered cores.

Well Correlations

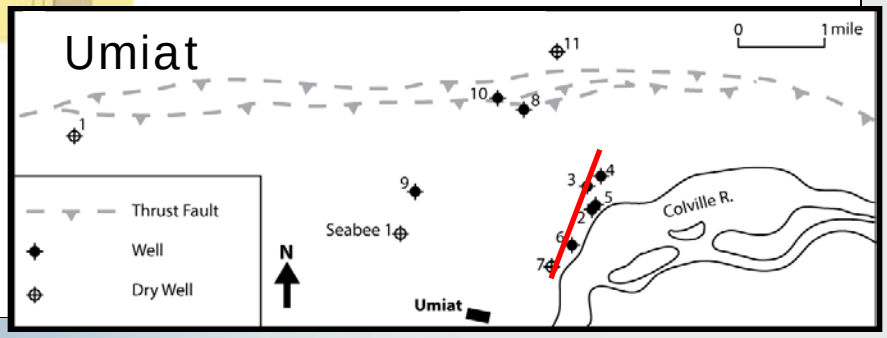


Southeastern wells

- closely grouped
- facies associations
- connectivity
- sand body thicknesses

Color Key

- FA 1: Offshore
- FA 2: Shoreface
- FA 3: Distributary Mouth Bar
- FA 4: Distributary Channel
- FA 5: Bay fill/Estuarine
- FA 6: Delta Plain
- FA 7: Fluvial Channel



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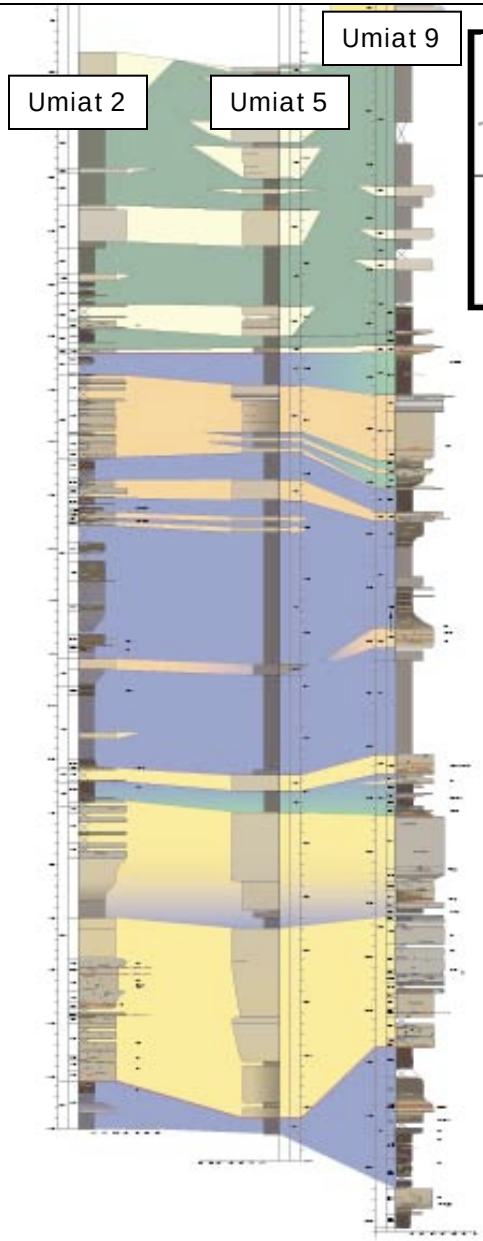

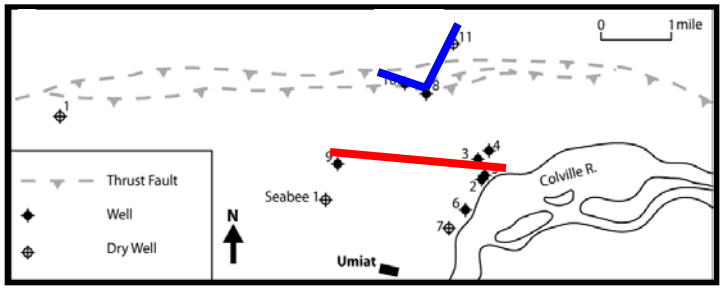

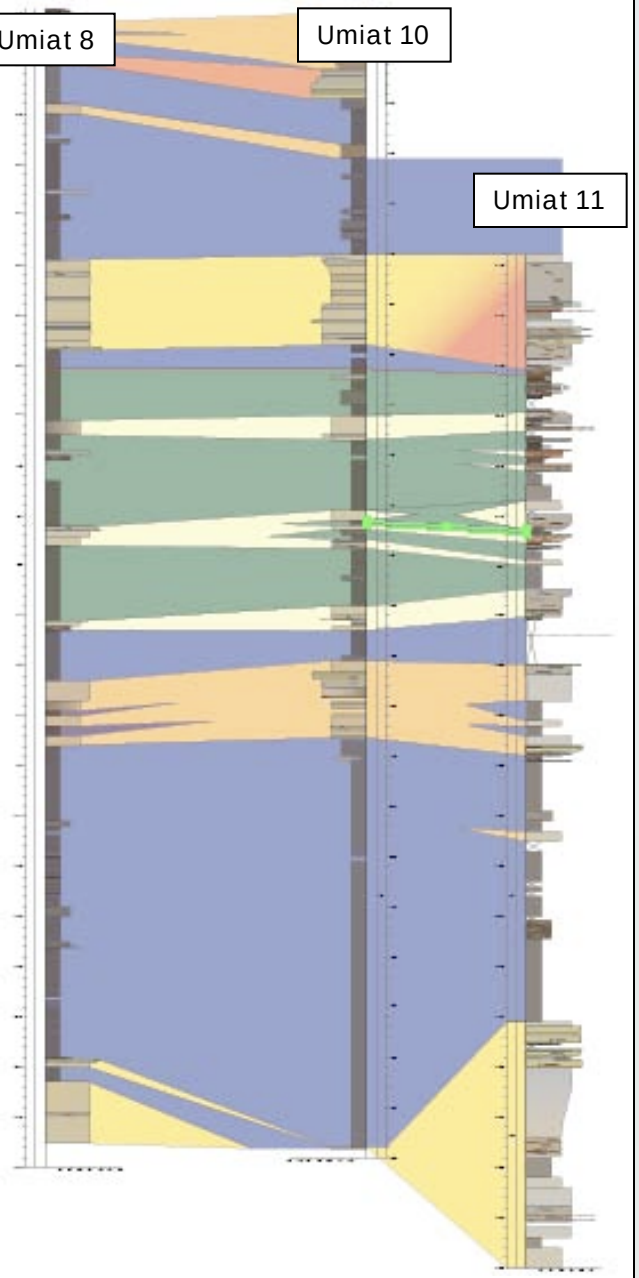

Variation across Umiat field

- east to west
  - thinner sand bodies
  - flow barriers
  - connectivity
- northern wells
  - fewer, thinner sands
  - thicker shales
  - faulting?

Summary and Conclusions

Umiat: an unconventional reservoir

- permafrost conditions require detailed facies analysis at Umiat
- 7 marine, non-marine facies described within the Nanushuk Fm.
- 3 reservoir facies associations
    - storm influenced shoreface, distributary mouth bar in the "Grandstand"
    - fluvial channels in the "Chandler"
- subsurface distribution of facies associations
    - shoreface and distributary mouth bar facies are well-connected in the subsurface
    - fluvial channel sands are less predictable

Future Work

- permeability characterization of Umiat cores using permeameter measurements
- assess impact of sedimentary structures and bioturbation on permeability
- enter results into reservoir modeling software

Acknowledgements

Project funded by US Department of Energy. Field support provided by the Alaska Division of Geological and Geophysical Surveys. Special thanks to Marwan Wartes, David LePain, and Paul Decker of the Alaska DGGS/DOG, as well as Kenneth Papp and the staff of the Alaska Geologic Materials Center.

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